DEVELOPMENT OF CROSS LAYER PULSE-BASED ULTRA-WIDEBAND COMMUNICATION SYSTEM FOR SHORT RANGE WIRELESS APPLICATION.

MUHAMMAD FADHLY BIN IDRIS SHAH

This report is submitted in Partial Fulfillment of Requirement for Award of Bachelor of Electronic Engineering (Wireless Communication) With Honours

Faculty of Electronics and Computer Engineering

Universiti Teknikal Malaysia Melaka

JUNE 2015

UNIVERSTI TEKNIKAL MALAYSIA MELAKA

FAKULTI KEJURUTERAAN ELEKTRONIK DAN KEJURUTERAAN KOMPUTER

BORANG PENGESAHAN STATUS LAPORAN

PROJEK SARJANA MUDA II

Tajuk Projek : **DEVELOPMENT OF CROSS LAYER PULSE-BUSED ULTRA-WIDEBAND COMMUNICATION SYSTEM FOR SHORT RANGE WIRELESS APPLICATION.**

Sesi Pengajian :

1	4	/	1	5

Saya, **MUHAMMAD FADHLY BIN IDRIS SHAH**
mengaku membenarkan Laporan Projek Sarjana Muda ini disimpan di Perpustakaan dengan syarat-syarat kegunaan seperti berikut:

1. Laporan adalah hakmilik Universiti Teknikal Malaysia Melaka.
2. Perpustakaan dibenarkan membuat salinan untuk tujuan pengajian sahaja.
3. Perpustakaan dibenarkan membuat salinan laporan ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. Sila tandakan (√) :

☐ **SULIT*** — *(Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia seperti yang termaktub di dalam AKTA RAHSIA RASMI 1972)

☐ **TERHAD**** — **(Mengandungi maklumat terhad yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)

☐ **TIDAK TERHAD**

Disahkan oleh:

_________________________ __________________________________

(TANDATANGAN PENULIS) (COP DAN TANDATANGAN PENYELIA)

Tarikh: .... Tarikh: ....

"I hereby declare that this report is the result of my own work except for quotes as cited in the references."

Signature :

Author : Muhammad Fadhly Bin Idris Shah

Date :

"I hereby declare that I have read this report and in my opinion this report is sufficient in terms of the scope and quality for the award of the Bachelor of Electronic Engineering (Wireless Communication) With Honours."

Signature :

Author : Dr. Mohammed Saeed Jawad

Date :

ACKNOWLEDGEMENT

Alhamdulillah, Praise to Allah S.W.T for giving me the chance and guidance in completing this thesis for my Final Year Project as part of the requirement for award of Bachelor of Electronic Engineering (Wireless Communication) With Honours. I am pleased to thank everyone who supported me either direct or indirect in giving me ideas and share their opinion. Especially, I owe my deepest gratitude to my supervisor, Dr Mohammed Saeed Jawad for his support, guidance, advice, and willingness to help and encourage me in completing the final year project. I am fortunate to have him as my advisors.

I would like to thank to my family especially my parents, Idris Shah Bin Mohd Yusof and Siti Mariam Binti Saad for their love, patient, moral supports and prayer along my study at Universiti Teknikal Malaysia Melaka (UTeM). Their fully supports as given me enough strength and inspiration in pursuing my ambition in life as well as to complete this project. Moreover, I would never forget the help I got from all my friend, especially my colleagues who give me encouragement, support, and idea in doing my Final Year Project.

During completing this Final Year Project (FYP) and report, I face a lots of problems and difficulties. However, I manage to crossed it all with patience and complete it appropriately. The journey in completing Final Year Project (FYP) and report really teach me in terms of leadership, proper time management, communication skill, technical knowledge, soft skill and so many more. The advice and encouragement from supervisor is really inspired me to do the best. Syukur Alhamdulillah, I have managed to complete my final year project and gained valuable knowledge and experience during this period of time. May Allah S.W.T repay all the kindness and bless all of us.

ABSTRACT

Impulse radio Ultra-wideband technology has been the motivation of many recent researches with the potential of many applications to be researched. The uniqueness of the physical characteristics of the generated signal combined with the high flexibility for different data rates at the physical layer design have been addressed in considerable number of researches recently. This research paper presents the introduction of the Impulse radio Ultra-wideband, the literature review for this project, and methodology of the project. Such in depth review can help to have a better understanding of the different possibilities of designing new impulse radio ultra-wideband solution for the future potential communications scenarios. The data analysis of the result also been discussed in this paper. The data analysis consists of two part; MATLAB and SIMULINK. In MATLAB, the codes is debugged and the results is compared to analyse the performance of the receiver based on different parameters. Then, the receiver model for UWB communication is constructed on SIMULINK as it will serve as real-time communication system. This research project is focused more on Pulse Position Modulation and Pulse Amplitude Modulation techniques and Time-Hopping and Direct Sequence are chose as spreading spectrum scheme for this research. As the research been done, IR-UWB proved that this technology is a suitable candidate as cognitive radio solution for next generation of wireless network.

ABSTRAK

Teknologi *Impulse Radio Ultra-Wideband* (IR-UWB) telah menjadi motivasi bagi banyak penyelidikan dengan potensi untuk pelbagai aplikasi untuk dikaji. Keunikan ciri-ciri fizikal oleh isyarat yang dijanakan dengan fleksibiliti yang tinggi untuk kadar data yang berbeza pada reka bentuk lapisan fizikal telah dibuktikan oleh banyak kajian baru-baru ini. Kertas penyelidikan ini membentangkan tentang penganalan bagi IR-UWB, kajian literature bagi penyelidikan ini, dan metodologi bagi penyelidikan ini. Kajian yang mendalam boleh membantu untuk mepunyai pemahaman yang lebih baik mengenai kemungkinan yang berbeza untuk mereka bentuk satu penyelasaian bagi IR-UWB untuk potensi senario komunikasi masa depan. Analisis data daripada hasil penyelidikan turut dibincangkan dalam kertas ini. Analisis data tebahagi kepada dua bahagian; MATLAB dan SIMULINK. Dalam MATLAB, kod-kod di simulasi dan hasilnya dibandingkan untuk menganalisa prestasi penerima isyarat berdasarkan parameter-parameter yang berbeza. Kemudian, model penerima bagi komunikasi *Ultra-Wideband* dibina pada SIMULINK kerana ia akan berfungsi sebagai system komunikasi masa nyata. Projek penelidikan ini memberi tumpuan pada teknik *Pulse Position Modulation* dan teknik *Pulse Amplitude Modulation* dan *Time-Hopping* dan *Direct-Sequence* dipilih sebagai skim sebaran spektrum untuk penyelidikan ini. Dengan penyelidikan yang telah dilakukan, IR-UWB membuktikan bahawa teknologi ini adalah calon yang sesuai sebagai penyelesaian radio kognitif untuk generasi rangkaian tanpa wayar.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF FUNCTION

LIST OF APPENDIX

LIST OF ABBREVIATION

UWB	**-**	**Ultra-Wideband**
IR-UWB	**-**	**Impulse Radio Ultra-Wideband**
TH	**-**	**Time Hopping Spreading spectrum**
DS	**-**	**Direct Sequence Spreading Spectrum**
PPM	**-**	**Pulse Position Modulation**
PAM	**-**	**Pulse Amplitude Modulation**
SNR	**-**	**Signal-to-Noise Ratio**
AWGN	**-**	**Adaptive White Gaussian Noise**
BER	**-**	**Bit Error rates**
LOS	**-**	**Line-of-Sight**
IEEE	**-**	**Institute of Electrical and Electronics Engineers**
MAC	**-**	**Media Access Control Layer**
PHY	**-**	**Physical Layer**
CDMA	**-**	**Code Division Multiple Access**
TDMA	**-**	**Time Division Multiple Access**
FDMA	**-**	**Frequency Division Multiple Access**
OSI	**-**	**Open System Interconnection Model**
FCC	**-**	**Federal Communications Commission**
GUI	**-**	**Graphical User Interference**

CHAPTER I

INTRODUCTION

This section discusses the overall of research project, including the research motivation, introduction to cross layer pulse based ultra-wideband, project objectives, problem statement, scope of work, brief explanation on methodology, and report organization.

1.1 Research Motivation.

The rapid development in wireless communication application has made data communication have significant importance of interest and increasing need in our life nowadays. However, several challenges such as traffic congestion, spectrum scarcity, power efficiency, interference between multiple users and environment fading still stand obstacle in the way of widespread use of the wireless communication technology. Therefore, wireless network elements including nodes, protocol layers, policies and behavior, are limited and unable to make intelligent adaptations to overcome such mentioned problems and offer a new featured services such as providing ubiquitous wireless access or increasing the data rate of current systems. Although a huge amount of the spectrum sits idle at a specific time, one of the main reasons, which limits the ability of these elements of providing new featured services, is that we suffer from the lack of spectrum. In order to prevent the interference between adjacent systems usually the designer will give each system exclusive access to certain block of spectrum. Thus, there is a need to understand how to design and control the wireless application that lies beyond what the current theory can provide.

1.2 Introduction to Cross Layer Pulse Based Ultra-wideband

Ultra-wideband is defined as any signal that occupies more than 500MHz bandwidth and impulse radio is a form of ultra-wide band signalling, has properties that make it a viable candidate for short range communications in dense multipath environments [5]. As an example, impulse radio ultra-wideband is widely used in tracking and position detection, radar imaging in medical health applications, and military radar application.

This technology comes with much more advantages compared to its disadvantages. Among its advantages are immune to multipath fading effects, highly secure wireless signal due to the spreading over very wide band of the spectrum, resistance to noise, and accurate position detection resolution up to centimetre. Pulse-based ultra-wideband is highly tuneable at the physical layer level (pulse repetition interval, pulse shape, pulse modulation) making this technology as cognitive radio solution for next generation of wireless sensor network [11]. Cognitive radio solution means pulse-based ultra-wideband can respond dynamically to the changes happened at the surrounding environment and other wireless neighbouring nodes. Therefore, ultra-wideband technology has proven to be useful in short range, high data rate, robust, and low power communication [18].

There are several challenges facing in designing this technology. One challenge is robustness to interference and poor radio propagation. With the increasing deployment of wireless network, uncontrolled interference becomes problematic. Uncontrolled interference typically occurs due to several independent networks functioning in close vicinity to each other. Furthermore, these network might be operated in hostile environment with poor radio propagation properties, for instance heavy multipath in indoor environments. Another challenge is low power consumption and low radiated power [23]. For environment and health concern, as well as coexistence with other wireless technologies, it is important that the level of radiated power per node be kept very low.

From a network design point of view. These challenges are cross layer. They concern not only the choice and design of an appropriate physical layer, but also the design of the upper layers. For physical layer, impulse radio ultra-wideband (IR-UWB) appears to have the potential to overcome this challenges. The large bandwidth of ultra-wideband radio, typically on the order of the gigahertz (GHz), allows for the resolution of multipath component [32]. This property combined with the use of proper radio receiver, offers a great resistance to multipath fading that usually plagues narrow-band radios. The wide bandwidth also provides robustness to interference. The large number of degree of freedom can be shared by several communications. In practice, time hopping can provide multiple access to an impulse radio ultra-wideband physical layer. In low data rate setting, it allows presumption for many asynchronous and noncurrent transmission with few interferences between simultaneous transmissions.

Because of their very wide bandwidth that would overlap with the bandwidth of existing system, there are stringent radio spectrum regulations already in effect in several countries. Consequently, ultra-wideband system are also characterized by extremely low power spectral density. Hence, an impulse radio ultra-wideband physical layer might provide both robust communication and raging capabilities for dense and low data rate wireless network scenarios. In fact, an impulse radio ultra-wideband physical layer has been chosen for the IEEE 802.15.4a amendment to IEEE 802.15.4, a standard that targets low data rate wireless network with extensive battery life and low complexity [8]. An ultra-wideband physical layer is also attractive in high data rate settings. The wide bandwidth is then not shared among several transmission, but used by only one to pack as many bits as possible.

The properties of ultra-wideband physical layer are very different than those of narrow-band physical layers. As such, the design rules and the architecture of a composed of impulse radio ultra-wideband nodes are likely to be fundamentally different than those for narrow-band wireless networks. Two of the main task of the media access layer (MAC) are to manage interference and multiple access to the physical layer. Existing wireless media access layer protocols for narrow-band or code division multiple access (CDMA) physical layers mostly employ mutual exclusive schemes, or power control, or a combinational of both. Time division multiple access (TDMA) is an example of classic mutual exclusive schemes [15]. They are used because of the assumption that simultaneous transmission result in transmission error. With mutual exclusive, interference is simply prevented. In contrast, thanks to the robustness of impulse radio ultra-wideband physical layers, it might well be that an exclusion scheme is not necessary. Then, allowing and intelligently managing interference might actually provide a better utilization of the resources and prove to be more efficient. For instance, power control is a well-known way to manage interference. But there are also less commonly exploited dimensions for interference management. In particular, rate adaption where the rate is adapted to the level of interference.

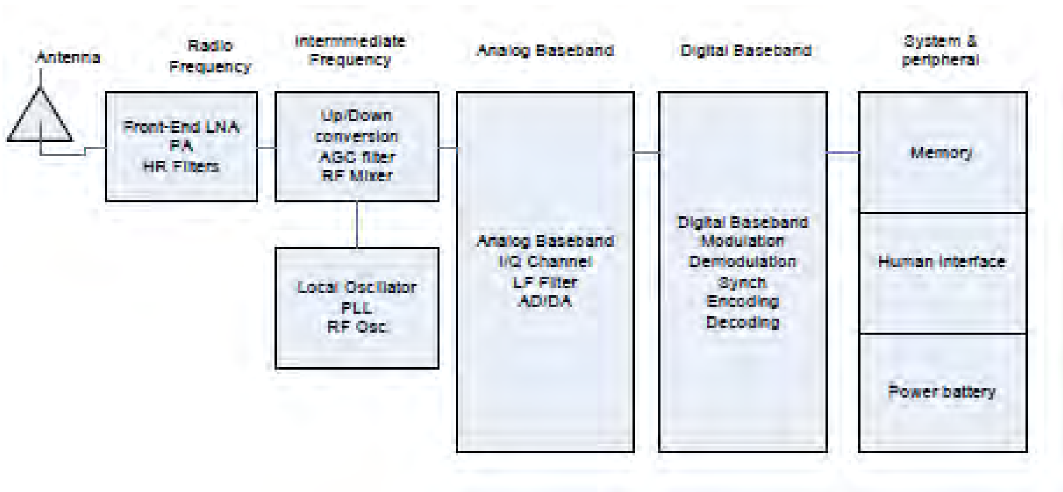

Figure 1.2.1: Narrowband Transceiver Architecture

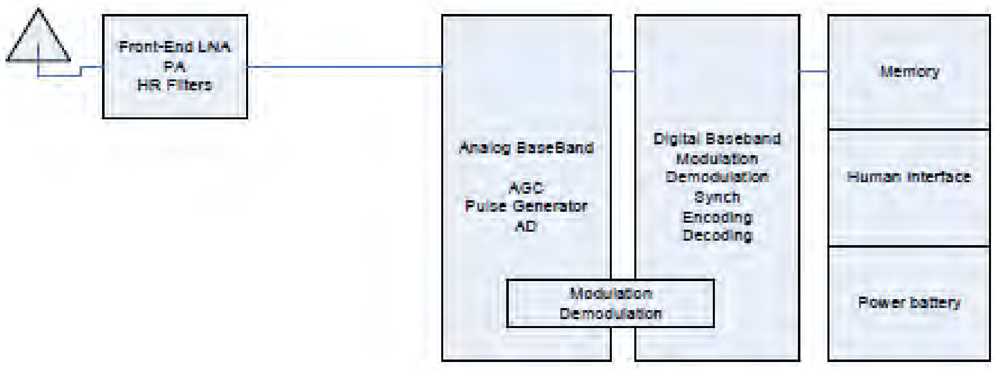

Figure 1.2.2: Ultra-wideband Transceiver Architecture

Table 1.2.1: Comparison Narrow-band and Ultra-wideband Communication System

	Ultra-Wideband	**Narrow Band**
Antennas	• Small with gain and wide bandwidth. • Good wide-band matching.	• Small high-Q antenna can be easily achieved with good gain. • Easy to match.
RF front end	• Automatic gain control is part of the front end. • Relaxed requirements on linearity.	Tough filtering is needed to satisfy out-of-band emission.
Intermediate frequency	Not needed	Mixer and RF oscillator

Analog baseband	Need very high bandwidth A/D converter digital sampling oscillator technique.	Small bandwidth A/D converter
Digital baseband	• Fine time resolution • Precise time references • Coherent detection	Non-coherent detection.
Channel aspects	Studies still ongoing.	Fading model

In wireless networking, information is exchanged between nodes using radio frequency signals. The various type of wiles networks can be grouped in different ways depending on the criteria chosen for its classification. The Open System Interconnection (OSI) reference model describes how information from a software application in one equipment through a network medium to a software application in another equipment. The OSI reference model is a conceptual model composed of seven layers, each specifying particular network function. This model divides the task involved with moving information between networked computers into seven smaller, more manageable task group. A group of task is then assigned to each of the seven layers. Each layer is reasonably self-contained so that the tasks assigned to each layer can be implemented independently. This enables the solutions offered by one layer to be updated without adversely affecting the other layer.

Physical layer is the level one in the seven OSI model of networking. This layer performs services requested by the data link layer. This level refers to network hardware physical cabling or wireless electromagnetic connection. [16] It also deals with electrical specifications, collision control and other low function. This layer is considered as the most basic network layer, providing only the means of transmitting raw bits. The major functions performed by the physical layer are:

- Conversion between the representations of digital data in user equipment and the corresponding signals transmitted over are communications channel.
- Participation in the process whereby the communication resources are effectively shared among multiple users.
- Establishment and termination of a connection to communication medium.

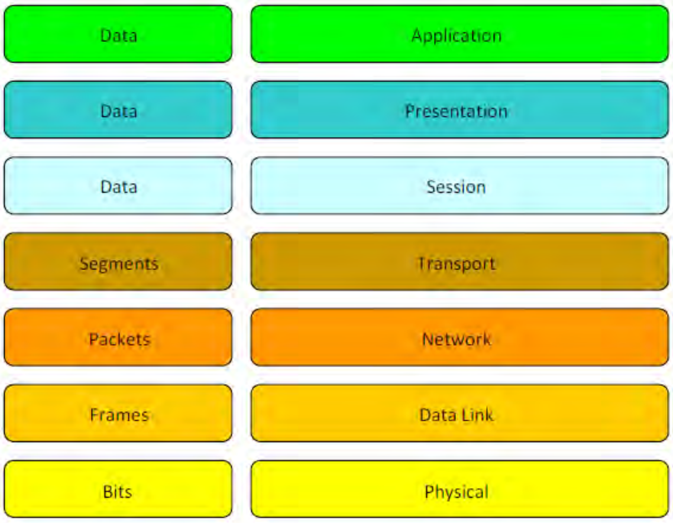

Figure 1.2.3: The Seven Layer of the OSI Model

The media access control (MAC) layers is the lower sub-layer of the data link layer and placed directly on the top of the physical layer. The upper sub-layer of media access control is the Logical Link Control layer, usually the network layer which presents a uniform interface to the user of the data link service. Media access control (MAC) layer is responsible to guarantee the communication operation between two nodes. In a wireless environment, the communication between the nodes is done via a radio, so its need a protocol to regulate the use of the medium, this task done through the channel access mechanism. The channel access mechanism is to determine which node can access the medium and at what time, it tells each node when it can transmit and when it is expected to receive data.

Referring to this protocol, which regulates the usage of the medium as media access control (MAC) protocol. This protocol determines the state of the radio on a node. In wireless network, the radio can be in one or two states, either in active state; transmit or receive data or idle state; free. The media access control sub-layer is primarily concerned with recognizing the beginning and the end of frames in the bit-stream received from the physical layer (when receiving) or delimiting the frames (when sending). Accordingly, the receivers are able to recognize the start and the end of the frames. Detection of transmission error by means of inserting a checksum into every frame sent and recalculating and comparing them on the receiver side, inserting the source and destination media access control addresses into every frame transmitted filtering out the frames intended for the station by verifying the destination address in the received frames [14].

In real environment, many users are simultaneously trying to establish connection with each other, which impose considerable challenge in wireless networking. The common challenge in wireless networking is interference, resulting from two nodes sending data at the same time over the same transmission medium or channel. Note that the source and the destination nodes could be far away from each other and each time packets need to be relayed from one nodes to another node. Accessing medium properly requires only informing the nodes within the vicinity of transmission. Therefore, media access control (MAC) protocols deals only with per-link communications, not with the end-to-end communications.

Therefore, many media access control (MAC) protocol have been developed in traditional areas of wireless voice and data communication networks to assist each node to decide when and how to access the channel. This problem is also known as channel allocation or multiple access problem. In order to support everyone demand, there must be a way to share the communication medium. To achieve such mechanism, a multiple access scheme for multiplexing user communication is used. This multiplexing usually can be done in time (Time Division Multiple Access; FDMA), frequency (Frequency Division Multiple Access; FDMA), or code (Code Division Multiple Access; CDMA). Media access control (MAC) protocols are designed to control access to the transmission medium [15]. Their aim is to provide an orderly and efficient use of the common communication medium. This protocol are responsible for per-link connection establishment such as acquiring the medium and per-link connection cancellation.

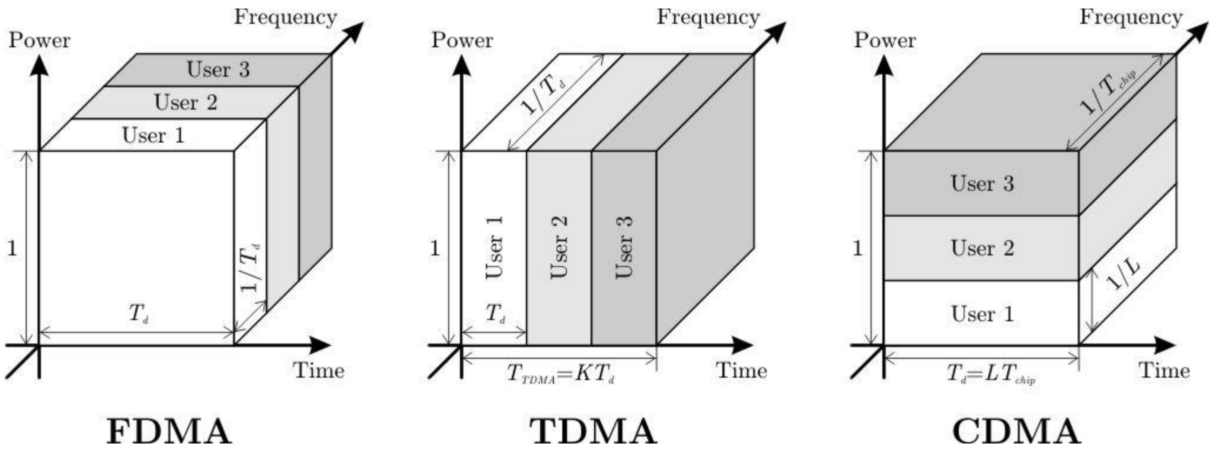

Figure 1.2.4: Multiple Access Schemes

Table 1.2.2: Comparison between TDMA, FDMA, and CDMA

Types	**Time Division Multiple Access (FDMA)**	**Frequency Division Multiple Access (FDMA)**	**Code Division Multiple Access (CDMA)**
Timing synchronization	Easy but requires overhead bits.	Requiring no extra overhead.	Difficult and requires synchronization channel.
Frequency synchronization	Easy but requires overhead bits.	Easy for gross synchronization.	More difficult.

Timing tracking	Modest complexity.	Usually not required within a burst/packet.	Complexity is high in asynchronous system.
Frequency tracking	Easy and decision-directed technique can be used	Additional overhead.	Modest complexity.
Channel equalization	Depending on bit rate and extent of delay spread.	Frequency Domain Equalisation is very easy.	More complex.
Analog Front-end	Very simple.	Complex.	Fairly complex.